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U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

INVESTIGATION OF SAND-CEMENT GROUTS

MISCELLANEOUS PAPER NO. 6-410

September 1960

U. S. Army Engineer Waterways Experiment Station
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Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS.

PREFACE

This paper was prepared as the result of a request from Mr. Stanley Johnson, Chairman of the Committee on Grouting Papers - Reno, American Society of Civil Engineers.

The paper was approved by the Chief of Engineers by first indorsement dated 28 March 1960 to Waterways Experiment Station letter dated 10 March 1960, subject, "Request for Permission for Publication," and was presented at the Reno, Nevada, American Society of Civil Engineers meeting of the Soils, Mechanics and Foundation Division, Session on Grouting, held the afternoon of 22 June 1960.

The data presented in this paper were taken from four reports of work performed at the Concrete Division, Waterways Experiment Station, and are as follows: Report No. 1, "Influence of Chemicals and Mineral Fines on Pumpability," Technical Memorandum No. 6-419, written by Messrs. Thomas B. Kennedy and James M. Polatty; Report No. 2, "Influence of Sand Grading and Addition of Mineral Fines on Pumpability," TM No. 6-419, written by Mr. J. M. Polatty; Report No. 3, "Influence of Grading and Specific Gravity of Manufactured Sands on Pumpability," TM No. 6-419, written by Mr. J. M. Polatty; Report No. 4, "Influence of Manufactured Sands and Admixtures on Pumpability, and Evaluation of a Colcrete Mixer," TM No. 6-419, written by Mr. Ralph A. Bendinelli.

All of the work was performed by personnel of the Concrete Division under the direction of Mr. Thomas B. Kennedy. Colonel Edmund H. Lang,

CE, was Director of the Waterways Experiment Station during the preparation of this paper. Mr. Joseph B. Tiffany was Technical Director.

INVESTIGATION OF SAND-CEMENT GROUTS

By JAMES M. POLATTY*

Introduction

The U. S. Army Engineer Waterways Experiment Station under the authorization of the Office, Chief of Engineers, and in connection with the Corps of Engineers Civil Works Investigation Programs, has conducted a number of studies on the pumpability of sanded grouts.

Due to the extensive use of grouting on Corps projects, it was felt that such a program could furnish much valuable information for both design and construction personnel, and could result in methods, procedures, and the usage of materials that would effect considerable cost savings and insure better results.

Purpose of Investigation

The purpose of the investigation was, in general, to determine the maximum amount of sand that could be used in a portland-cement grout without injuring its pumpability. In order to widen the scope of the investigation, different gradations and types of sands were test-pumped. In addition, the effect of various admixtures on sand pumpability, using sands that either were deficient in or contained ample amounts of materials passing the No. 100 sieve, were studied.

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Materials

A standard Type II cement complying with Federal Specification SS-C-192b was used in all of the test mixtures.

Three types of sand were used in the test mixtures: (1) a well-rounded natural siliceous sand from Mississippi with a 2.6 specific gravity, (2) a manufactured limestone sand from Tennessee with a 2.7 specific gravity, and (3) a diabase traprock manufactured sand with a 2.9 specific gravity.

The gradation given in OCE standard guide specification for concrete sand was used as a starting gradation for the sands. However, this specification allows an average of 35 per cent to be retained on the No. 16 sieve. By removing (by scalping) the material retained on this sieve, the resulting average gradation is the "10 per cent passing No. 100 sieve" as shown in fig. 1. In addition to this gradation, sufficient material passing the No. 100 sieve was either added or removed to produce sands with gradations of 0, 5, 15, and 25 per cent passing the No. 100 sieve for the natural sand and 0 and 15 per cent for the limestone and traprock sands. The gradations of the 0 and 25 per cent passing the No. 100 sieve are shown in fig. 1.

Five admixtures used in the investigation and their sources are as follows: diatomite, uncalcined, California; fly ash, Illinois; pumicite, California; loess, Mississippi; bentonite, Wyoming. Physical data for the materials used as mineral fines are given in table 1.

Equipment

The mixing, pumping, and circulating system consisted of a standard laboratory-type paddle mixer of approximately 37 gallons capacity, and an air-driven, simplex

2-1/2- by 3-1/4- by 5-in. grout pump. The mixtures were test-pumped through 200 ft of 3/4-in.-ID rubber hose which, after leaving the grout pump, rose vertically for 13 ft, made a 5-in.-radius turn, and returned to the pump elevation. The remainder of the hose was coiled in a 5-ft-minimum radius on the floor. The 200 ft of 3/4-in. hose consisted of four 50-ft sections, each section connected with a metal connector having a 5/8-in.-ID opening. Figure 2 shows the test pumping system.

Tests

Before the pumping test was begun, all materials were weighed out and the mixer, pump, and hose system thoroughly wetted. The water, cement, sand, and admixtures were then added in that order, except that the bentonite was first mixed with a small amount of cement and then with the water and sand before introducing the bulk of the cement. After thoroughly mixing, check consistency test was made using a piano wire torque consistency meter and water added, if necessary to maintain a uniform consistency of 135 ± 15 deg. During all pumping tests, an attempt was made to operate the pump at a rate of 70 strokes per minute.

After adjustments, the grout mixture was pumped through the hose system and the rate of flow determined. Then the hose system was shut off for a 15-minute period and the grout remaining in the mixer allowed to slowly by-pass through the pump and mixer.

After the 15-minute period was over, the hose line valves were opened slowly and the grout circulated. If it was possible to recirculate the grout after it had remained in a static condition in the hose line during the 15-minute period, the grout was judged pumpable. Three successful pumping tests were made for each combination reported pumpable.

At the end of the pumping tests, consistency, bleeding, and rate-of-flow tests were made and specimens were obtained for compressive strength and time-of-set tests. The line pressures and temperature of the grout were also recorded.

Test Program

The program to investigate the pumpability of portland cement-sand grout mixtures was divided into three general phases as follows:

(1) Phase I: The effect on the pumpability of grouts containing the three types of sand, each of which contained different percentages of materials passing the No. 100 sieve, was determined.

(2) Phase II: The effect of various admixtures on the pumpability of grouts containing the three types of sand with a nominal 0 per cent passing the No. 100 sieve was determined.

(3) Phase III: The effect of various admixtures on the pumpability of grouts containing two of the sands with a nominal 10 per cent passing the No. 100 sieve was determined.

Phase I

The first part of this phase consisted of tests to determine the maximum quantity of natural sand that could be pumped, using six different gradations of sand. These gradations were all basically similar except that the percentages passing the No. 100 sieve were 0, 5, 10, 15, 20, and 25. Table 2 gives the results of these tests. It can be noted that the sand content of the grouts found pumpable varied from two parts for a sand with 0 per cent passing the No. 100 sieve to three parts for the sand with 25 per cent passing the No. 100 sieve.

The second part of Phase I included tests to determine the limits of pumpability of a limestone sand. Based on the work done on natural sands, it was decided to use only the sands with 0, 10, and 15 per cent passing the No. 100 sieve. The tests indicated that the parts of manufactured limestone sand that could be pumped increased considerably with an increase in material passing the 100-mesh sieve, varying from 1.75 parts for 0 per cent to 7.0 parts for 25 per cent.

The third part of Phase I was performed to furnish information as to the maximum pumpability of three gradations of a sand with a higher than normal specific gravity. Traprock sand was used in gradations having 0, 10, and 25 per cent fine material passing the No. 100 sieve. As in the pumping test of the other sands, the quantity found pumpable varied from 1.75 parts for the 0 per cent fines to 2.25 parts for the 25 per cent.

The test data for the second and third parts of this phase are given in table 3, and the relation of the three types of sand to parts found pumpable are shown in figure 3.

Conclusions that may be drawn from this phase of the investigation are as follows:

(1) It is feasible to pump sanded grouts.

(2) Two parts of natural sand and 1.75 parts of limestone or traprock sand, containing a nominal 0 per cent of material passing the No. 100 sieve, based on part of cement were found to be pumpable.

(3) An increase in the material passing the No. 100 sieve from 0 to 25 per cent allowed only an increase of one part of natural and 0.5 parts of traprock sands, while the parts of limestone sand increased from 1.75 to 7. An analysis of the material passing the No. 100 sieve indicates that the

limestone sand fines have about three times the surface area and seven times the amount of minus No. 325 material as does the traprock or silica sand. This is probably the reason for the difference in the quantity of sand found pumpable.

Phase II

The three types of sand used in this phase of the investigation were similar to those used in the first part of phase I for each type of the three sands test-pumped.

In the first part of this phase, natural sand with a nominal 0 per cent passing the No. 100 sieve and with the addition of various percentages of four admixtures, fly ash, loess, diatomite, and pumicite, was test-pumped. The results in figure 4 show that increasing the amount of admixtures allowed an increase in the amount of sand that could be pumped. As the diatomite had a specific surface about 10 times that of the loess, it would appear that this increase is dependent on the fineness of the admixture.

In the second part of this phase, limestone sand with the nominal 0 per cent passing the No. 100 sieve and with the addition of percentages of fly ash and loess was test-pumped. As in the first part of this phase, the parts of sand found pumpable were slightly greater for the mixtures containing percentages of fly ash than for those containing loess.

In the third part of this phase, traprock sand, deficient in material passing the No. 100 sieve, with the addition of percentages of fly ash was test-pumped. As in the other tests in this phase, the additions permitted an increase in the sand-carrying capacity of the grout mixture. The results of the pumping test for the second and third parts of this phase are plotted in figure 5. Table 4 gives the pumping-test data for the three types of sand test-pumped in this phase.

The tests conducted in Phase II indicate that:

(1) When a sand is deficient in materials passing the No. 100 sieve, the addition of finely divided mineral admixtures will increase the sand-carrying capacity of the grout mixture.

(2) The ability of a finely divided mineral admixture to increase the sand-carrying capacity of a grout appears to be related directly to its fineness.

Phase III

In the first part of this phase, the same natural sand was used that had been used in the other phases of this program with a gradation having 10 per cent passing the No. 100 sieve. Based on the weight of cement, percentages of diatomite and bentonite were added and their influence on the pumpability, or sand-carrying ability, and the characteristics of the grout mixtures in both plastic and hardened conditions were studied. The results indicated that the addition of percentages of 0.06 parts of diatomite permitted an increase of .75 in the parts of sand found pumpable, while an addition of 0.40 bentonite permitted an increase of 23 parts of sand.

The limestone sand used in the second part of this phase was the same as that used in phase I with 10 per cent passing the 100-mesh sieve. Percentages of diatomite and fly ash were added to the grout mixtures, as in the first part of this phase. The addition of one part of diatomite permitted an increase of [illegible].75 parts of sand found pumpable, while 1.5 parts of fly ash allowed an increase of 4.25 parts of sand. Table 5 lists the results of these pumping tests, and figure 6 illustrates the results graphically.

This phase of the investigation indicated that the addition of percentages of the various admixtures will increase the sand-carrying capacity of a sand-cement grout when sands with sufficient fines are being used. (10 per cent passing the No. 100 sieve).

It is believed that while the large addition of bentonite in these tests did permit a large increase in the amount of sand, the low strength that results when large quantities of sand are used would allow its use only in special cases.* In addition to the admixtures mentioned above, IP Fluidifier and Methocel were investigated; both materials permitted an increase in parts of sand found pumpable.

General Conclusions

A number of conclusions can be drawn from the data obtained in this investigation, among which are:

(1) Sand deficient in material passing the No. 100 sieve can be successfully pumped in grout mixtures without the use of an admixture.

(2) Concrete sands can be used in portland-cement grout mixtures provided they are scalped over the No. 16 sieve.

(3) An increase in fine material in the minus No. 100 sieve size will permit an increase in the quantity of sand found pumpable.

(4) Manufactured sands can be successfully pumped in portland cement-sand grout mixtures.

(5) The specific gravity of the sands included in this test program had little or no effect on the pumping characteristics of the grout.

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* This is not to imply in any case that small quantities of bentonite are not useful in pressure grouting.

(6) In using sand deficient in minus No. 100 sieve size material, the addition of a finely divided mineral admixture increases the sand-carrying capacity of the grout.

(7) The addition of a finely divided mineral admixture to a normal portland cement-sand grout will increase its sand-carrying ability.

Table 1

Investigation of Sand-Cement Grouts
Data on the Physical Properties of the Finely
Divided Mineral Admixtures

Type Admixture	Specific Gravity	Blaine Specific Surface, sq cm/g	% Passing No. 325 Sieve
Fly Ash	2.52	3,580	94
Pumicite	2.34	5,220	98
Loess	2.66	1,800	96
Diatomite	2.25	20,300	97
Bentonite	2.40	155,000	99

Table 2

Phase I - Investigation of Sand-Cement Grouts Containing Natural Sand with Varying Percentages Passing the No. 100 Sieve

Sand % Passing No. 100 Sieve	Proportions by Wt Based on One Part of Cement		Time of Set, hr		Bleeding, %	Cube Compressive Strength, psi	
	Sand	Water	Initial	Final		7 Day	28 Day
0	2.0	0.63	4	7+	1.2	1750	3500
5	2.50	0.72	4	8+	1.6	1350	2800
10	2.50	0.76	5	8+	1.7	1550	3050
15	2.75	0.82	4	8+	1.7	1400	2700
20	2.75	0.82	4	-	2.7	1300	2500
25	3.00	0.87	4	7+	3.5	1050	2100

Table 3

Phase I - Investigation of Sand-Cement Grouts Containing Limestone and Traprock Sands with Varying Percentages Passing the No. 100 Sieve

Sand % Passing No. 100 Sieve	Proportions by Wt Based on One Part of Cement: Sand	Water	Time of Set, hr: Initial	Final	Bleeding, %	Cube Compressive Strength, psi: 7 Day	28 Day
			Limestone Sand				
0	1.75	0.66	6+	17-	0.9	1795	3780
10	3.25	1.08	7+	18	1.3	660	1405
25	7.00	1.95	7+	70-	1.7	160	340
			Traprock Sand				
0	1.75	0.68	5	16-	1.8	2020	4565
10	2.00	0.72	6	21-	1.6	1315	3180
25	2.25	0.83	6	17-	2.1	1265	2830

Table 4

Phase II - Investigation of Sand-Cement Grouts Containing Sands with 0 Per Cent Passing No. 100 Sieve Effect of Admixtures on Pumpability

Type Admixture	Proportions by Wt Based on One Part of Cement: Admixture	Sand	Water	Time of Set hr: Initial	Final	Bleeding, %	Cube Compressive Strength, psi: 7 Day	28 Day
				Natural Sand				
No Admixture	-	2.00	0.63	4	7	1.2	1730	3505
Fly Ash	0.11	3.10	0.88	6	21-	1.5	1195	2210
Fly Ash	1.00	6.50	1.62	7+	26	1.3	435	715
Loess	0.11	2.80	0.88	5+	18-	1.3	1300	2355
Loess	1.00	6.00	1.88	2+	50-	1.2	255	410
Diatomite	0.11	3.90	1.19	6	20-	1.2	585	1035
Diatomite	1.00	9.00	3.18	6+	19-	0.4	55	235
Pumicite	0.11	3.10	0.94	3+	17-	1.8	1095	1965
Pumicite	1.00	6.50	2.04	3+	26	1.9	170	380
				Limestone Sand				
No Admixture	-	1.75	0.66	6+	17-	0.9	1795	3780
Fly Ash	0.11	1.90	0.73	6+	18-	0.9	1650	3370
Fly Ash	1.00	5.00	1.58	7+	24	0.9	595	1385
Loess	0.11	1.90	0.74	5	19	0.8	1595	3000
Loess	1.00	4.50	1.62	6+	21	1.0	265	535
				Traprock Sand				
No Admixture	-	1.75	0.68	5	16-	1.8	2020	4565
Fly Ash	0.11	1.94	0.73	4+	16-	1.5	1435	3420
Fly Ash	1.00	4.50	1.49	7+	22-	1.4	710	1450

Table 5

Phase III - Investigation of Sand-Cement Grouts Containing Sands with 10 Per Cent Passing No. 100 Sieve Effect of Admixtures on Pumpability

Type Admixture	Proportions by Wt Based on One Part of Cement			Time of Set hr		Bleeding, %	Cube Compressive Strength, psi	
	Admixture	Sand	Water	Initial	Final		7 Day	28 Day
				Natural Sand				
No Admixture	-	2.50	0.76	5	8+	1.7	1540	3030
Diatomite	0.03	3.00	0.95	4+	21	-	860	1840
Diatomite	0.06	3.25	1.01	3+	19	-	745	1900
Bentonite	0.025	4.0	1.35	8+	22-	-	375	670
Bentonite	0.40	32.0	12.17	70+	500+	-	0	0
				Limestone Sand				
No Admixture	-	3.25	1.08	7+	18	1.3	660	1405
Diatomite	0.11	4.50	1.54	4+	19-	1.7	355	805
Diatomite	1.00	12.00	4.17	3+	82-	0.6	75	255
Fly Ash	0.25	3.75	1.18	4+	20-	1.1	800	1515
Fly Ash	1.50	7.5	2.10	3+	23	0.8	440	1025